

A Photocurable Resin–Electrolyte Platform for High-Resolution Electrochemical Metal Additive Manufacturing

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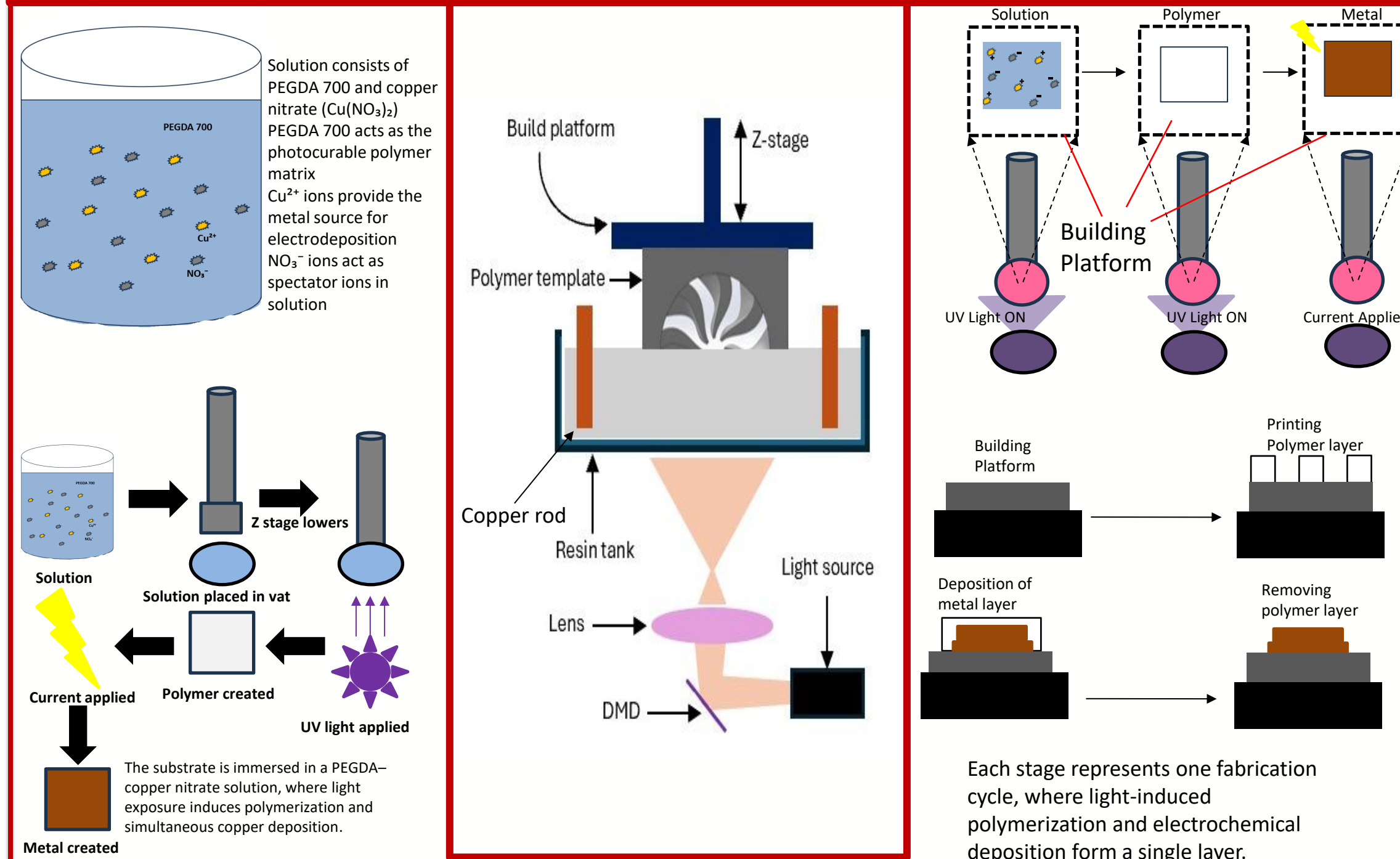
Abstract

Electrochemical additive manufacturing (ECAM) offers a lower energy alternative to metal 3D but remains limited by slow builds and scalability hardships. This project investigates a photocurable resin-electrolyte process that allows for localized, layer-by-layer deposition at room temperature. By integrating photopolymerization with electrochemical deposition, the proposed method aims to improve spatial control, fabrication efficiency, and precision. This approach has potential to advance small scale manufacturing for applications in electronics, sensors, and devices.

Research Objective

The objective of this project is to develop and evaluate a photocurable resin–electrolyte process for electrochemical additive manufacturing that enables precise, layer-by-layer metal deposition at room temperature. This work aims to investigate the effects of key process parameters, including applied current, electrolyte composition, and layer thickness, to improve spatial control, fabrication efficiency, and structural quality of printed metal microstructures.

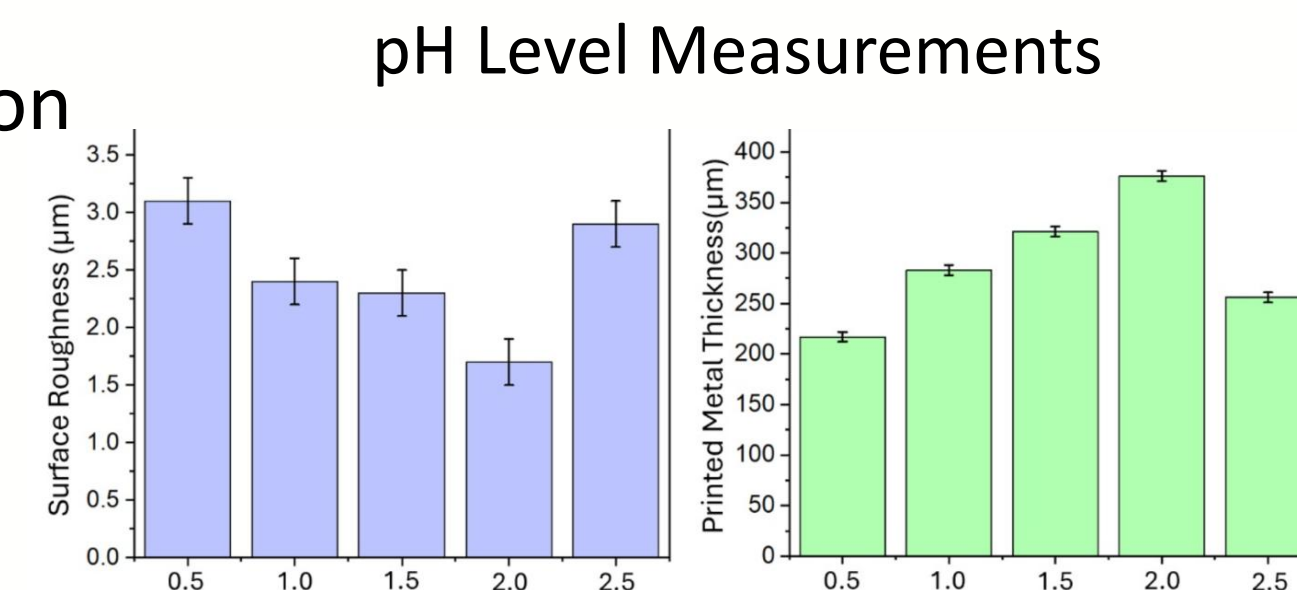
Method



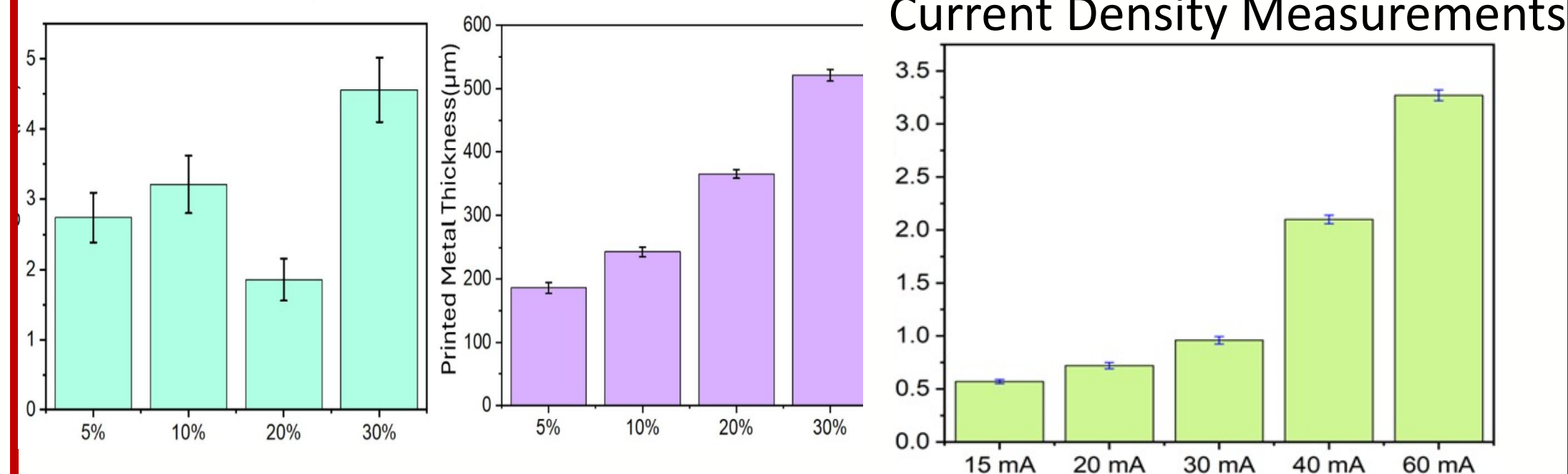
Results and Discussion

Optimization of Process Parameters

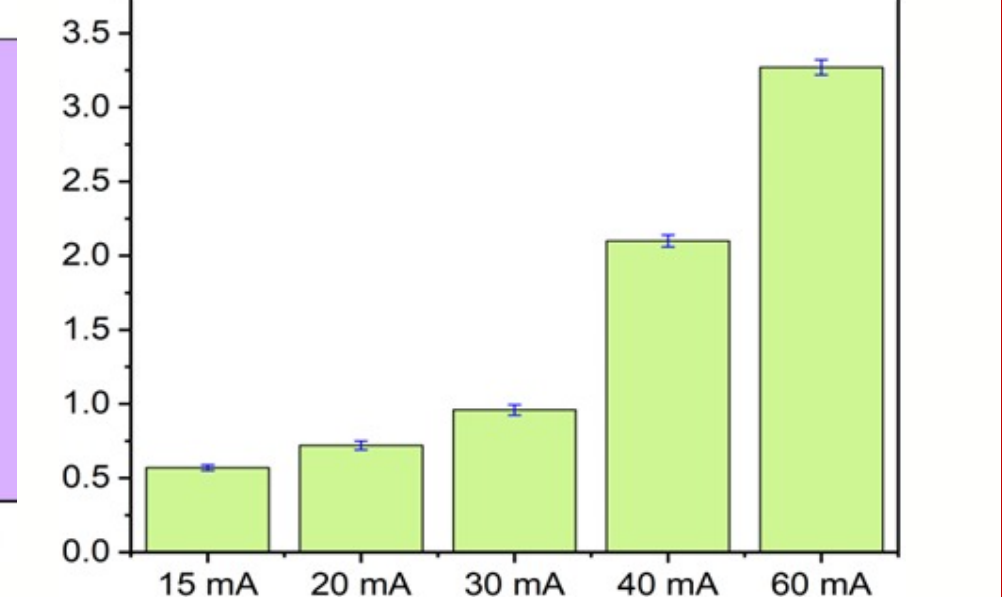
1. pH Level
2. Additive Concentration
3. Current Density
4. Curing Depth
5. Layer Thickness



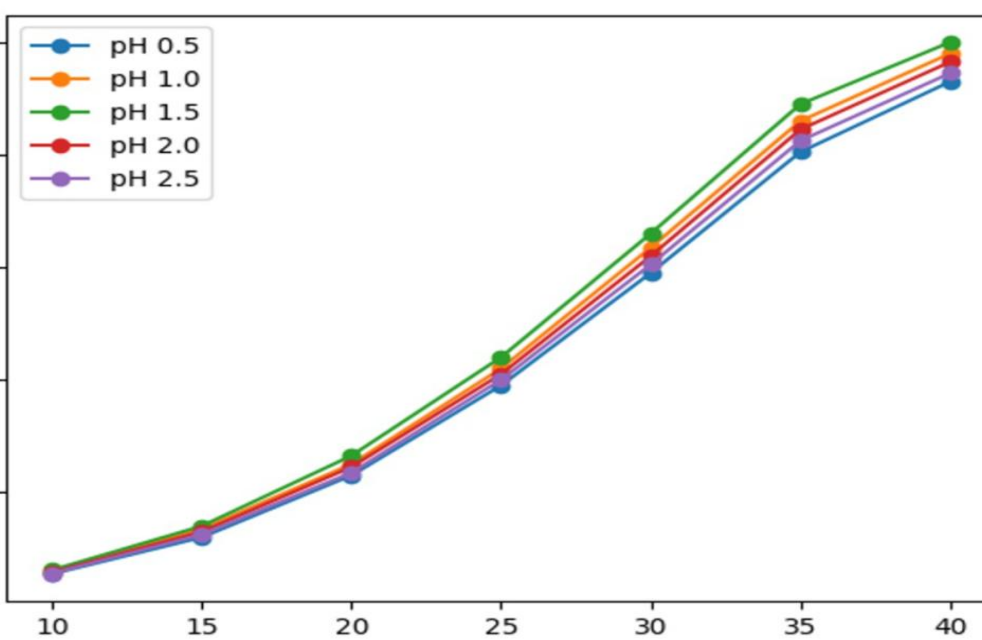
Additive Concentration Measurements



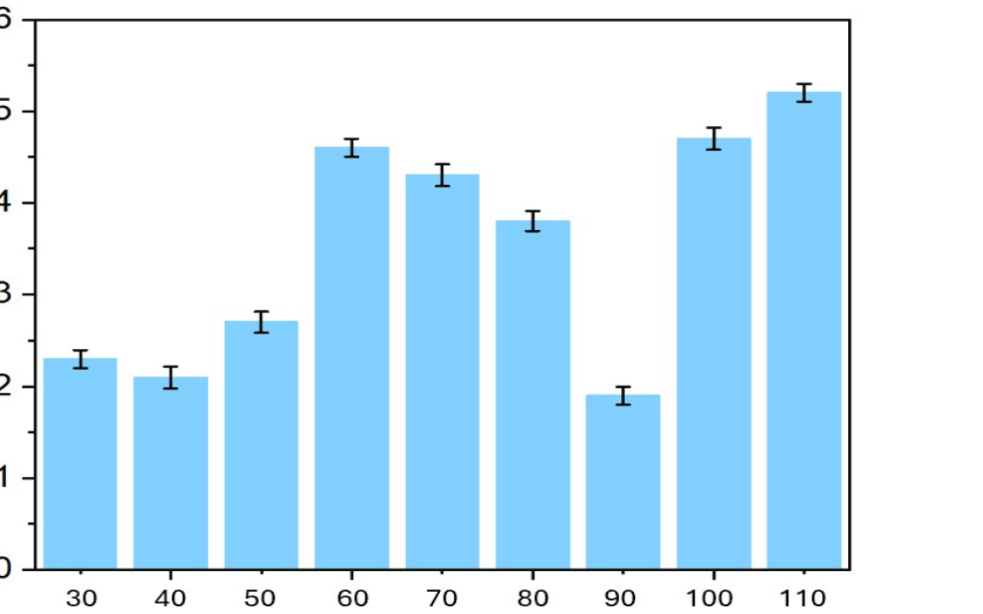
Current Density Measurements



Curing Depth Measurements

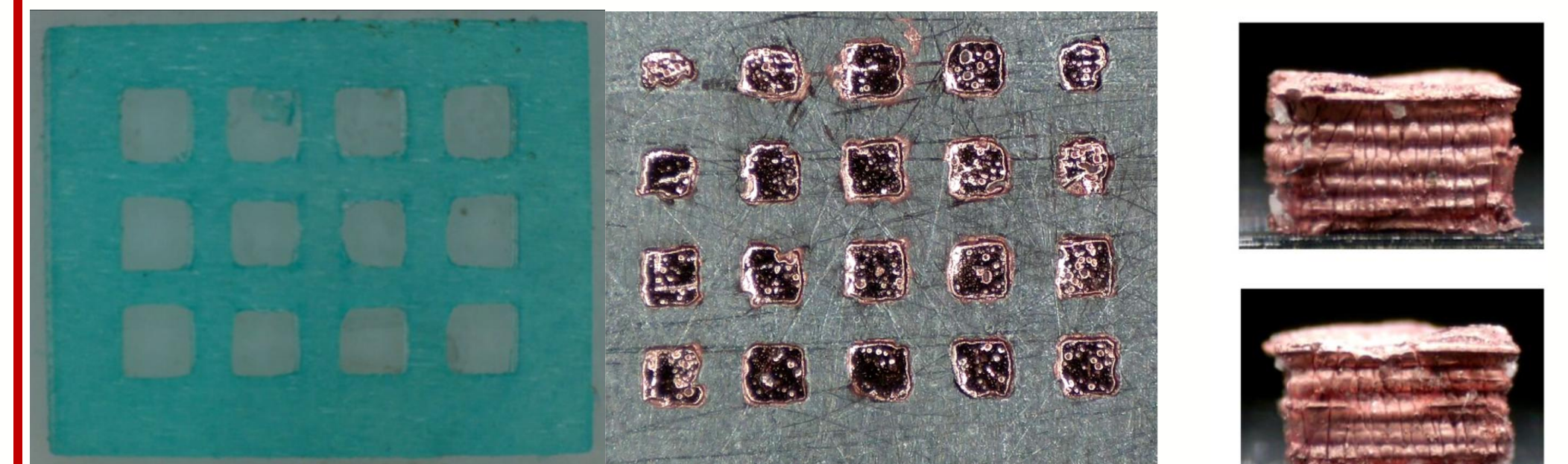


Layer Thickness Measurements

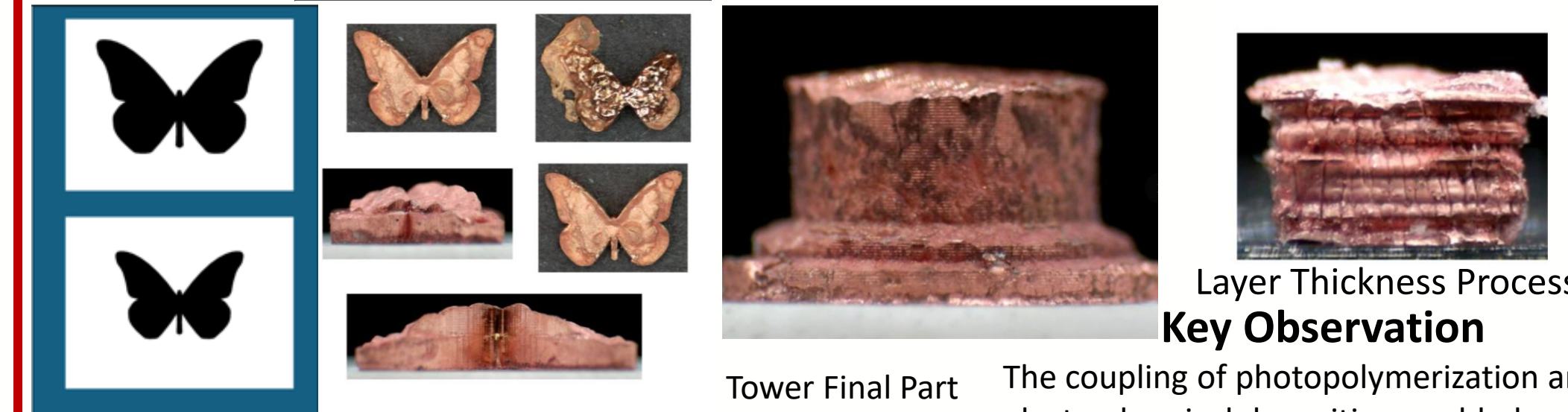


Optimization of the electrochemical additive manufacturing process was performed to achieve uniform and stable metal growth. Under non-optimized conditions, the process resulted in non-uniform deposition and reduced adhesion, whereas optimized parameters produced more consistent layer formation and improved structural integrity. Process conditions were selected based on literature and refined through iterative testing to balance deposition rate, surface quality, and layer uniformity. In particular, optimizing pH and current density was critical for achieving controlled, repeatable fabrication and enhancing overall print quality.

Process Capability and Demonstration



Polymer and metal prints of the current smallest possible size of 700 micrometers



Butterfly Final Part, Tower Final Part, Layer Thickness Process, Key Observation: The coupling of photopolymerization and electrochemical deposition enabled localized and controlled material growth.

Future Work

Future work will focus on further improving the adhesion and mechanical stability of printed structures through material and process optimization, while also exploring multi-material integration to enable more complex and functional designs. In addition, efforts will be directed toward investigating the scalability of the process for larger and more intricate geometries, as well as refining key parameters to optimize resolution and surface finish, ultimately enhancing the overall performance, reliability, and applicability of the manufacturing approach.

Acknowledgements

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[3] Han, D., Lu, Z., Chester, S. A., et al. Micro 3D Printing of a Temperature-Responsive Hydrogel Using Projection Micro-Stereolithography. *Sci Rep*, 8, 1963 (2018). <https://doi.org/10.1038/s41598-018-20385-2>

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